CHAPTER 6

IMPLEMENTING A LOCAL FLOOD WARNING SYSTEM

6.0 Introduction

This section describes the steps in the process of implementing a flood warning system. The LFWS needs to be linked to the response system to produce benefits of flood recognition. Steps to producing an effective response system are not discussed in this document.

- System Design
- Alternate Uses
- Memorandum of Understanding
- Procurement
- Installation
- Maintenance
- Backup System
- Transmitter Licenses

6.1 System Design

The process of determining the need and feasibility of implementing an LFWS will generate critical information required for its design. Through the support of the NWS, other Federal, state, and local agencies, and/or private consultants, the local flood risk will have been assessed, the type of local organization determined, and the financial and sociopolitical support defined. All of the following components of the warning system must be integrated into detailed design documents:

- Measurement and detection
- Data transmission
- Data processing and analysis
- Forecast preparation
- Forecast dissemination

Design may be accomplished through local resources supported by NWS or private consultants.

The software selection, such as NWS ALERT, IFLOWS, and private vendor offerings, will influence the system design. The types, number, and location of gages, as well as their transmission paths to collection points, must be specified.

Prior to the procurement of equipment and as part of system design, all transmitter license approvals must be obtained from the Federal Communication Commission (FCC) (see Section 6.8).

6.1.1 Rain Gages

Number. The number of rain gages installed in an LFWS directly affects its performance. Generally, the more gages, the better the chances of detecting flood-producing rainfall. The number of gages required will depend to a large extent on the rainfall variability in the local area. Therefore, to adequately depict rainfall over a basin, mountainous areas usually will require more gages than flat lands. Areas subject to local convective storms will require more gages than areas that generally experience larger-scale, frontal-type storms. Obviously, availability of funds must also be factored in when determining the number of gages to be installed.

Extensive studies have been made at the Massachusetts Institute of Technology, Stanford University, the NWS, and others, on the spatial variability of precipitation and the number of rain gages needed to predict flood crests. For planning purposes, the number of rain gages required to make a reasonably accurate flood prediction is dependent primarily on the river basin area. The following list suggests the minimum number of gages per river basin area (in square miles).

Number of Rain Gages	River Basin Area (square miles)
3	< 40
4	100
6	400
8	1,000

Exposure. Rain gages should be located on ground level and should not be located close to isolated obstructions, such as trees and buildings, that may cause erratic turbulence and affect the accuracy of the gage catch. Gages should also not be located in wide-open spaces or on elevated sites. The best location is where the gage is uniformly protected in all directions, such as an opening in a grove of trees. If a precipitation gage is near an object, then the distance between the gage and the object should be at least twice the height of the object.

6.1.2 Stream Gages

Stream gages provide information about the current state of the stream. In small watersheds, typical of those associated with LFWSs, streamflow observations are used to calibrate watershed models, verify forecasts from models, or trigger alarms when flooding is impending or occurring. The location of stream gages in an LFWS are guided by one or both of the following factors: (1) downstream public warning requirements and (2) forecast model requirements. Gages used for stage alarms should be located at key points of potential damage and at points that are far enough upstream to yield enough warning time for downstream locations.

6.1.3 Communication Media

LFWSs generally impose few restrictions upon communications design. Consequently, communications design varies depending on the desired area of coverage and resources available for transmission equipment. Currently, LFWSs exist which use VHF or UHF radio, microwave, satellite, dedicated leased telephone lines, or a combination thereof. A brief description of the more common communication elements for automated data collection follows.

Event-Reporting Hydrometeorological Sensors. These sensors are battery-powered, microprocessor-controlled counters interfaced with a modulator and VHF-FM radio transmitter.

Single-Frequency Repeater. The single-frequency repeater is used to extend the radio transmission range of event-reporting sensors. It receives an incoming signal, waits until the entire signal has been received, and regenerates and retransmits it on the same radio frequency.

Microwave Radio System. A microwave system is a series of back-to-back repeater transceivers that are capable of carrying many independent channels at the same time over long distances. Any site in a microwave system can, with the proper interfaces, provide audio communication with one or more sites in the system.

Radio Transceiver. Generally, a radio transceiver is used to extend communications beyond the limit of a microwave or other backbone communications system. Transceivers located at mountaintop sites are called “repeaters,” and transceivers located at endpoints in the system are called “base stations.”

Base Station. A base station is a final destination in the LFWS communications network. Data directly from sensors or repeaters, telephone lines, etc., are received by appropriate interface equipment and transmitted to the base station microcomputer. The computer accepts observation reports, processes and validates information, displays it as required by the users, and forwards data to the appropriate NWS computer, such as AWIPS.

Once local warning and response requirements have been determined, communication engineering expertise should be solicited to define the various communications media options that are available to meet requirements and their associated costs.

6.2 Alternate Uses

Increasing numbers of Federal, state, and local agencies are becoming involved in the implementation and operation of LFWS technology. These programs cover a broad spectrum of real-time environmental sensing. Applications cover highway safety, pollution control, and water management, for example. It may prove more efficient and cost effective for an organization to integrate flood recognition with other local program needs. At the very least, several programs could share the cost and utility of the various data collected. Another very

important advantage is that a multipurpose system tends to be used and maintained regularly, ensuring reliable operations during flood episodes.

6.3 Memorandum of Understanding

When implementing an LFWS, both the NWS and the LFWS operator will benefit from an MOU that describes how the parties will cooperate and share in the support for the LFWS. A sample MOU for an automated LFWS and a manual LFWS are contained in Appendix A.

6.4 Procurement

There are two basic approaches for local procurement of the hardware for the LFWS. The first is to purchase the various hardware components from individual vendors (e.g., gages, radio repeaters, and modems from one vendor; computers from another; and possibly a network transceiver from a third vendor). The second approach is to purchase all required hardware from a single vendor specializing in supplying integrated warning system configurations. Information on possible vendors may be obtained from the ALERT Users Group (AUG), the Southwestern Association of ALERT Systems (SAAS), and IFLOWS Management (refer to Sections 11.11, 11.12, and 11.14, respectively) or from various hydrometeorological professional societies.

6.5 Installation

Communities may find it feasible and cost effective to use local government support (such as the highway department, civil works department, or others) to install much of the hardware for the LFWS. It may be necessary to supplement resident support with local vendor support, particularly for installing and testing data transmission equipment. There are vendors who specialize in both supplying and installing complete warning system configurations.

A limited amount of software installation support for NWS-provided software can be provided by NWS. The local U.S. Geological Survey (USGS) office can provide guidance on proper installation procedures for stream-level sensors.

6.6 Maintenance

Proper maintenance of the LFWS is essential for its successful operation. The maintenance program must cover all elements of the LFWS: gages, data transmission system, software and computer, and preparedness/response system. Preventive (routine) maintenance schedules associated with the various hardware components should be followed. Because of the events-reporting nature of sensor platforms, the sensors and system must be operational at all times. Periodic testing of equipment is important. Some diagnostic "tools" are built into ALERT/IFLOWS equipment and software. The ALERT/IFLOWS gage transmitters are

programmed to transmit twice a day for diagnostic purposes. There are diagnostic routines in the IFLOWS software that indicate potential radio communication problems.

Those users associated with the local FWU must be trained and kept current on their roles and responsibilities. Conducting practice drills in concert with the NWS, at routine intervals, has proven valuable in keeping the system at a high level of readiness. The local agency must prepare for life-cycle equipment replacement. The gages and communication equipment have useful (maintainable) life spans of about 10 years. The computer hardware life span is about 3 to 5 years. Generally, maintenance and life-cycle replacement costs each run around 10 percent of capital investment per year.

6.6.1 Funds for Maintenance

A community may use various funding sources (general local tax base, special surcharge, general/private donations, etc., or combinations thereof) to fund maintenance. Whichever method is chosen, it is important that it can produce recurring funds for the long term. As mentioned above, a rough estimate for maintenance funding is 10 percent per year of the initial capital cost of the LFWS.

6.6.2 Recommended Routine and Preventative Hardware Maintenance

Routine maintenance for all field sites should be scheduled at least once, and preferably twice, each year for servicing of the following equipment:

ALERT/IFLOWS Battery Gage

1. Set up a rotating battery-change schedule at least twice per year, less frequently if solar panels are used.
2. Check battery voltage, every visit. Check voltage before and during transmission.
3. Check battery terminals for corrosion or loose terminals/connections, every visit.
4. Check battery level to avoid dropping below manufacturer's specifications, every visit.
5. Follow battery manufacturer's instructions for discharging battery prior to recharging.

Note: A solar panel charging system is highly recommended as part of the field installation.

Antenna

1. Position antenna elements so that they are not directly above the rain gage's collector.
2. Check reflective power in and out.
3. Do visual inspection for gunshots or missing elements. Look for broken or exposed antenna cable.

4. Check antenna clamps to be sure bolts are tight and verify antenna direction.
5. Plug top of antenna mast; keep water out of standpipe.

Rain Gage Unit

1. Check rain gage tipping bucket mechanism for proper balance, every visit.
2. Check for spider webs, wasp nests, bird droppings, or other debris in the funnel, every visit.
3. Check rain gage housing to be sure it is secured, every visit.
4. Calibrate and clean rain gage tipping bucket, at least once per year.
5. Seal bottom of tipping bucket housing with waterproof sealer.
6. Make sure all holding screws are in place and tight so that the tipping bucket remains level in high winds and/or with some pushing on the standpipe.

Water Level Sensor (Shaft Encoder)

1. Check reed switches when unit will not hold calibration.
2. Rotate wheel several turns to make sure chain doesn't jump off sprocket, every visit.
3. Check wires at terminal block and plug with ohmmeter, every visit.
4. Calibrate to ensure accuracy, every visit.

Water Level Pressure Transducer

1. Check for vandalism and for biological fouling, silting, sand, wood, plastic, etc, every visit.
2. Check to make sure straps are holding, every visit. Replace straps or add more if movement is noticed.
3. Check pressure transducer plug at transmitter for loose or broken wires, every visit.
4. Reseal any electronic components in a liquid epoxy, when necessary.

Sensor Transmitter

1. Clean radio frequency link device, once per year.
2. Disconnect, clean, and reconnect the connections between main board, back board, and plug-in sockets to ensure positive electrical contact, once per year.
3. Measure output in watts, every visit.
4. Replace desiccant pack, once per year.

Standpipes

1. Re-level pipes if required.
2. Seal any gunshot holes.

Base Station (Computer/Software/Radios)

1. Check station, daily.
2. Execute all commands and run all menu selections to make sure all are working properly, twice a month.
3. Switch to standby power on a regular schedule to ensure proper operation.

Repeater

1. Check battery and connections, every visit.
2. Check antennae for damage, every visit.
3. Check coaxial transmission line and connectors to antennae for damage, every visit.
4. Check commercial power and/or solar panel and connecting cables, every visit.

Spare Equipment

1. Keep spares on hand (at least 10 percent recommended) of each type of equipment used in the overall LFWS.
2. Exchange or test spare equipment, monthly.
3. Store equipment in a clean, dry environment.

Additional maintenance information is available from the Internet web sites of the AUG and SAAS listed in Sections 11.11 and 11.12, respectively.

6.6.3 Emergency Maintenance

ALERT/IFLOWS gages are programmed to report twice a day. If gaged data are not being received as scheduled, initiate emergency maintenance to check suspected gage malfunctions. If there is a store-and-forward repeater in the LFWS and a large number of gages appear not to be reporting, the likely culprit is the repeater.

A spare parts inventory should be maintained. This is particularly important for the electronics packages of the gages and repeaters.

6.7 Backup System

The NWS advises some backup for the automated LFWS. To ensure the integrity of its local flood warning effort, the community should maintain an auxiliary power supply (uninterruptible power supply, generator) and a backup data collection capability (redundant radio paths, radios, and computer). Where such backup cannot be automated, it may be necessary to establish a network of observers to report at least rainfall and river stages when the automated system is not functioning. Although circumstances vary, many areas of the country have found computerized backup to be less expensive and more reliable than maintaining an auxiliary network of observers.

If the LFWS includes a forecast model on a computer and other backup is not available, a manual forecast procedure should be readily available. Numerous manual forecast procedures in the form of simple look-up tables have been used for years and serve as an effective backup process during critical flood situations. The last portion of Appendix B of this Handbook contains an example of a manual forecast procedure.

6.8 Transmitter Licenses

Many LFWSs transmit data via line-of-site radio signals. Transmission of these signals requires that licenses be obtained from the FCC through a process outlined in the subsections below. The FCC has set up specific procedures for obtaining licenses for the transmission of hydrologic data, which is the category that LFWS data come under. The FCC has reserved frequencies that are strictly for the transmission of hydrologic data. They are in the VHF band (169.425 to 171.925 MHZ) and in the UHF band (406.125 to 412.775 MHZ).

6.8.1 Coordination

For Federal agencies, application must be made to the Interdepartment Radio Advisory Committee (IRAC) through the Hydrologic Radio Frequency Coordination Group (HRFCG). The HRFCG of the Hydrology Subcommittee of IACWD reviews all applications for use of frequencies in the hydrologic bands, checks for possible impacts on already existing users of the frequencies, and recommends acceptance or rejection, based on its findings, to the IRAC and FCC. The IACWD committee has members from all Federal agencies that deal with water data.

For non-Federal agencies (e.g., counties, cities, etc.), application must be made to the FCC through the HRFCG. As part of the application, the non-Federal user must have a letter from a Federal agency verifying that agency is a cooperator in the hydrologic data collection system. All non-Federal users of these frequencies are secondary to Federal Government station users, and the hydrometeorological data being transmitted must be made freely available on request to government agencies.

The membership of the HRFCG includes representatives from the TVA and the Departments of Agriculture, Defense, Energy, Interior, and Commerce. The NWS representative serves as the permanent chairperson of the HRFCG.

6.8.2 Frequencies for Hydrologic Purposes

The HRFCG recommends to the IRAC and to the FCC the assignment of specific frequencies in the bands allocated for use jointly by Federal agencies and non-Federal users for transmission of hydrometeorological data for hydrologic purposes.

Specific frequencies allocated primarily for hydrologic purposes are (in MHZ):

169.425	170.225	171.025	171.825
169.4375	170.2375	171.0375	171.8375
169.450*	170.250	171.050	171.850
169.4625	170.2625	171.0625	171.8625
169.475	170.275	171.075*	171.875
169.4875	170.2875	171.0875	171.8875
169.500	170.300	171.100	171.900
169.5125	170.3125	171.1125	171.9125
169.525	170.325	171.125	171.925
406.125	409.675	412.625	412.725
406.175	409.725	412.675	412.775

* frequencies that are shared with the Department of the Treasury and are being phased out for hydrologic purposes

6.8.3 Application Process for Federal Agency

A. Applications by a Federal agency desiring use of hydrologic radio frequencies or in cooperation with a non-Federal user should be made through appropriate NWS channels to:

Hydrologic Radio Frequency Coordinator
Office of Hydrology (W/OH2), SSMC2
NOAA, National Weather Service
1325 East-West Highway
Silver Spring, MD 20910-3283

Applications by non-Federal users wishing to hold the license but having the NWS as the Federal Cooperator may be made directly by the non-Federal user to the above address. The approval process can be quite lengthy, usually taking 4-6 months. When establishing new stations, begin the process as soon as site coordinates have been accurately established.

Submit an original and nine copies of the application to the above address. The application consists of a memorandum describing the proposed plan of operation and the following information for each proposed station (see the example in Figure 6-1):

1. Location name;
2. Type of station (sensing, repeater, base station, etc.) [specify sensing type (precipitation, river stage, etc.) in the remarks column];
3. Location of gages, etc. (latitude and longitude to nearest second);
4. Frequency or frequencies required. Indicate transmitting (T) and receiving (R) frequencies;

5. Output power of transmitter in watts;
6. Antenna characteristics:
    a. antenna type (yagi, corner reflector, or collinear)
    b. orientation if directional (three-digit number in degrees from true north or nondirectional, as appropriate)
    c. gain in decibels (dB);
7. Height of antenna above ground (feet);
8. Gage site (ground) elevation (feet MSL);
9. Necessary band width of emission expressed in kilohertz using the letter K in lieu of the decimal (e.g., use 2K85 instead of 2.85 KHz);
10. Emission Classification Symbols (use "F2D");
11. Type of hydrologic data to be transmitted (precipitation, river stage, etc.);
12. Map showing location of transmitting and receiving stations and limits of operational area. A coordinate grid (latitude and longitude) should be shown on the map. When proposed stations are additions to or modifications of an existing network, the map should show the complete system that will exist after pending actions are completed.
13. Justify installation with an explanation of how the collected data will be used and why a radio is to be used in lieu of land lines.
14. Cooperating agencies, if any. (Non-Federal users must identify the cooperating Federal Government agency.)

B. The HRFCG Coordinator shall send a copy of the request to all group members for review and comment concerning the effect upon each of their agencies' operations and for an appraisal from each member as to the appropriateness of using the hydrologic frequency spectrum for the purpose intended. All requests for hydrologic frequencies are initially screened for two criteria:

1. A Federal agency must sponsor the applicant, and the applicant must share the LFWS data with that agency free of charge, although the agency need not be on the HRFCG.
2. The information transmitted must be of a hydrologic nature.

The group members shall check the request against other current applications and records of existing installations. When the request has received clearance from all group members, the Coordinator shall advise the applicant on behalf of the Hydrology Subcommittee and so advise the IRAC or FCC that formal application may be made to the Frequency Assignment Subcommittee of IRAC or the FCC for frequency assignment. A copy of the Coordinator's clearance letter should be used by the applicant to indicate that coordination has been accomplished.

C. If, under B above, group members present objections to the applicant's proposal, the Coordinator shall recommend counter-proposals. If a counter-proposal is acceptable, the Coordinator shall then advise the applicant of required revisions to the original proposal in order to overcome the objections. If group members cannot reach agreement on a request, that particular case shall be referred to the full Hydrology Subcommittee for decision.

D. Applications to IRAC (or FCC) for frequency assignments shall be made within 3 months following Hydrology Subcommittee action; otherwise, requests must be resubmitted to obtain clearance.

E. Any modification of existing networks or individual stations (where the data supplied under A(1) through (11) are changed) shall be submitted in writing to the Coordinator with an original and nine copies. This submission shall clearly describe the revised system or network with modifications to the original system or network. According to the nature of the change, the Coordinator shall effect the necessary coordination with appropriate committee members.

F. When the authorized frequency assignment(s) are no longer needed by Federal agencies, termination of the operation(s) should be reported through individual agency channels to the IRAC Frequency Assignment Subcommittee in addition to notifying the HRFCG Coordinator.

6.8.4 Application Process for the Non-Federal Agency

A non-Federal user desiring frequency assignments shall submit a request that provides the information outlined in 6.8.3A. Such requests shall be processed in accordance with paragraphs 6.8.3B through E above. If the Committee recommends favorably, the HRFCG Coordinator shall advise the applicant, IRAC, and FCC that there is no objection to making a formal application to the FCC for license. A copy of the approval letter from the HRFCG should be attached to the FCC application as proof that coordination has been accomplished. If a license is granted, the responsibility for the applicant's adherence to all legal requirements of the license rests with the FCC. In the event of unfavorable action by the Committee, the applicant and the FCC shall be so notified. The application process can be quite lengthy, usually taking 6 months.

6.8.5 Status Reports

At each regular meeting of the Hydrology Subcommittee, the HRFCG Coordinator shall report, for the record, on the status of pending and completed coordinations. Every effort shall be made to expedite actions if the need is so stated in the original request.

6.8.6 License Renewal

Licenses are valid for a period of 5 years. The agency that holds the license is responsible for renewing the license before the expiration date. Renewal is accomplished by applying for radio frequency as if for the first time (Sections 6.8.3 or 6.8.4 above). When anticipating license renewals, applicants should initiate requests approximately 6 months before the license expiration date.

6.8.7 Responsibility of Licensee

The NWS processes all requests for hydrologic frequency assignments and is often the agency that holds the license. The agency that is assigned these authorizations is responsible for the transmissions that take place. If the transmissions cause interference with another project, whoever holds the license will be ordered by the FCC to rectify the situation.

6.8.8 Reference

U.S. Department of Commerce, *Manual of Regulations and Procedures for Federal Radio Frequency Management*, National Telecommunications and Information Administration.

December 4, 1996

NAME: Flood City LFWS

Map No	Station Name	Station Type	Latitude North DD MM SS	Longitude West DD MM SS	Frequency Receive (MHZ)	Frequency Transm (MHZ)	Transm Power Watts	Antenna Type	Antenna Orient (Deg)	Antenna Gain (db)	Height Above (ft)	Site Elev (ft)	Band Width (KHZ)	Emission Classi-fication	Remarks
1	NEWVILLE	Sensing	41,23,08	84,48,06		171.025	8	OMNI		3	13	815	8K00	F2D	P, S, T
2	DECATUR	Sensing	40,50,55	84 56 16		169.425	8	OMNI		3	13	790	8K00	F2D	P, S
3	ANTHONY BLVD	Sensing	41,05,02	85,06,47		169.425	8	OMNI		3	13	750	8K00	F2D	P, S
4	AUBURN	Sensing	41,20,40	85,03,31		171.025	8	OMNI		3	13	880	8K00	F2D	P
5	IRENE BYRON	Sensing	41,11,56	85,10,25		171.025	8	OMNI		3	13	850	8K00	F2D	P
6	SMITH FIELD	Sensing	41,08,41	85,09,24		171.025	8	OMNI		3	13	835	8K00	F2D	P
7	SPY RUN	Sensing	41,06,30	85,08,54		169.425	8	OMNI		3	13	810	8K00	F2D	P
8	ROCKFORD	Sensing	40,41,40	84,38,54		170.300	8	OMNI		3	13	805	8K00	F2D	P, S, T
9	SALEM	Sensing	40,41,48	84,51,07		170.300	8	OMNI		3	13	815	8K00	F2D	P
10	POE	Sensing	40,56,11	85,05,18		169.425	8	OMNI		3	13	790	8K00	F2D	P
11	MULDOON ST	Sensing	40,59,16	85,06,03		169.425	8	OMNI		3	13	830	8K00	F2D	S
12	GRABILL	Repeater	41,12,36	84,58,04	171.025	169.425	25	DIR	210	7	50	820	8K00	F2D	
13	DECATUR	Repeater	40,50,20	84,55,31	170.300	169.425	25	DIR	315	7	80	790	8K00	F2D	
	ROOTS SKI HA	Sensing	41,09,12	85,04,43		169.425	8	OMNI		3	13	795	8K00	F2D	P, S
14	FORT WAYNE	Receiver	41,00,10	85,12,41	169.425		110	OMNI		5	60	791	8K00	F2D	

Figure 6-1. *Example of station information for license application.*